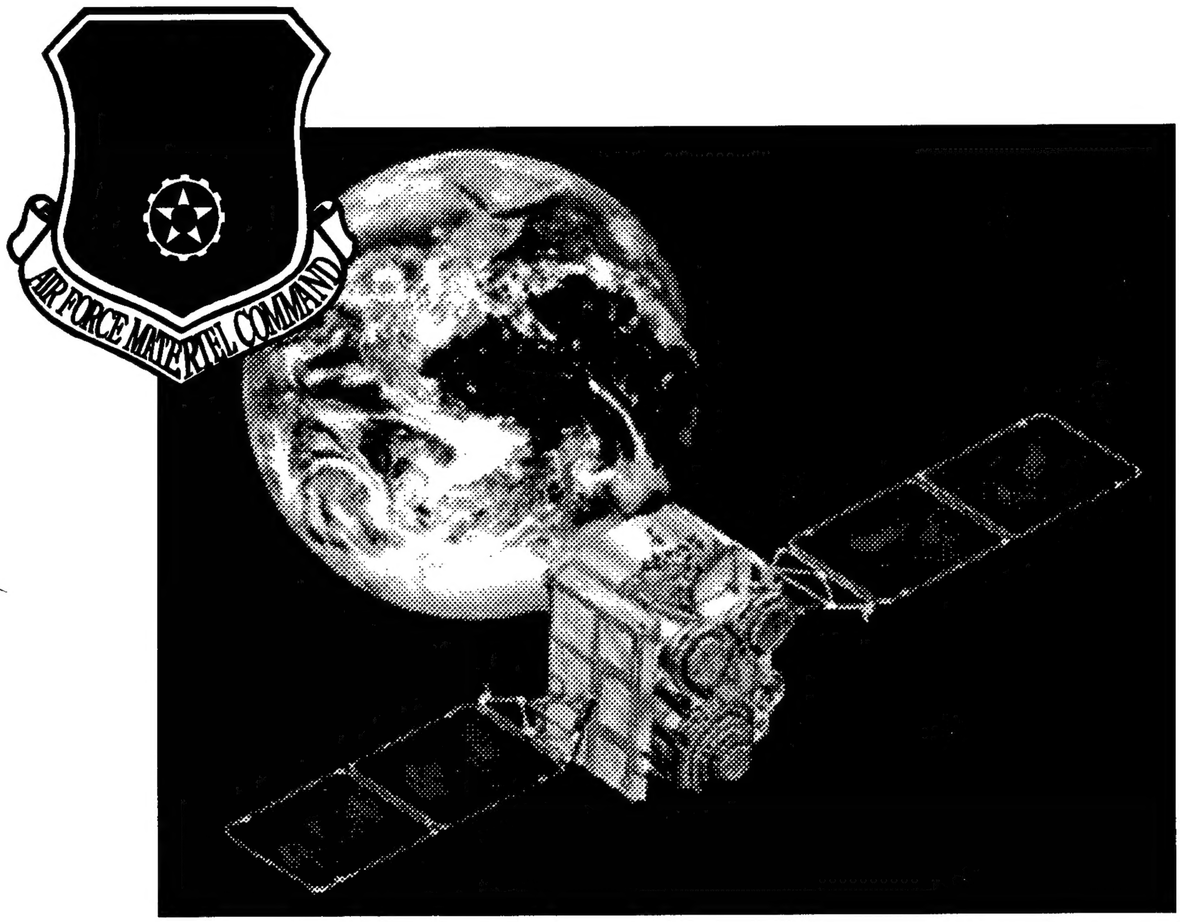
FY97
SPACE AND MISSILES
TECHNOLOGY AREA PLAN



HEADQUARTERS AIR FORCE MATERIEL COMMAND
DIRECTORATE OF SCIENCE & TECHNOLOGY
WRIGHT PATTERSON AFB, OH

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The FY97 Space and Missiles Technology Area Plan describes Phillips Laboratory's exploratory and advanced technology development strategy for Boost and Orbit Transfer Propulsion Technology, Tactical and Spacecraft Propulsion Technology, Space vehicle Structures and Controls, Advanced Technology Integration and Demonstration, Space Power and Thermal Management, Space Sensors and Satellite Communications, Space Vehicle Electronics and Satellite Control, Space Vehicle and Missile Dynamics Technology.

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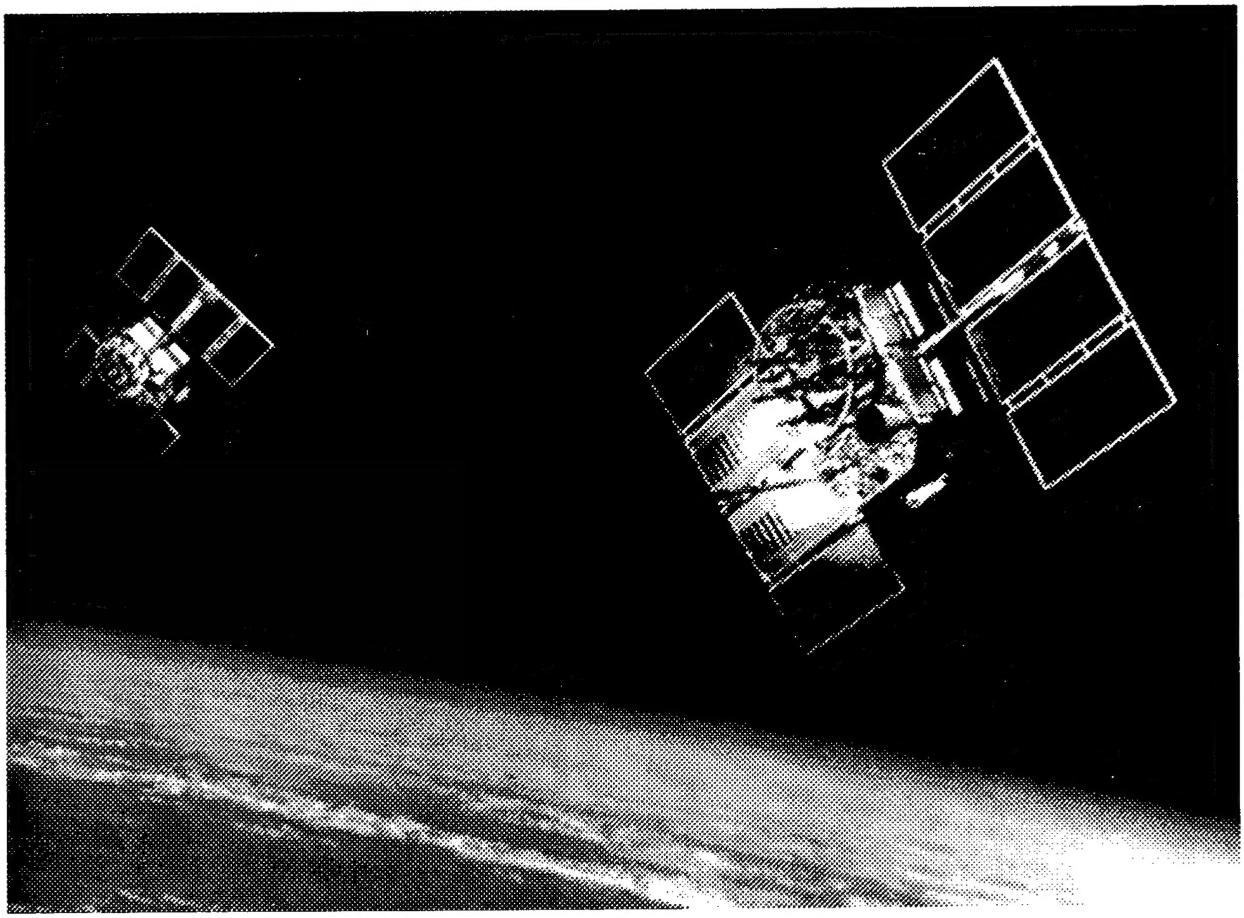

VISIONS AND OPPORTUNITIES

Rapid and cost effective development and transition of superior technologies for space and missile systems enable the affordable and decisive military capability of our US forces. This vision for the Space and Missiles Technology area is in concert with the Department of Defense Science and Technology (S&T) Strategy. The principle characteristic of US military strategy is technological superiority. We remain committed to developing the technologies that provide options for the warfighter, especially those capabilities that take advantage of space as an operating environment. However, we are responsive to the new reality that technological superiority alone is no longer sufficient. Our investments must consider affordability.

The specific technologies pursued in the Space and Missiles Technology area are driven by military needs specified by the warfighter and embodied in the five Future Joint Warfighting Capabilities:

1. To maintain near perfect knowledge of the enemy and communicate that to all forces in near-real time.
2. To engage regional forces promptly in decisive combat, on a global basis.
3. To employ a range of capabilities more suitable to actions at the lower end of the full range of military operations which allow achievement of military objectives with minimum casualties and collateral damage.
4. To control the use of space.
5. To counter the threat of weapons of mass destruction and future ballistic cruise missiles to the CONUS and deployed forces.

We respond to these user needs through the Air Force mission area planning process. These needs are described in terms of deficiencies, operational concepts, and technology needs to meet user requirements. We focus our technologies in the Space and Missiles Technology area to enable operational concepts either through technology development or rapid exploitation and transition of technological opportunities.

Ultimately, the Space and Missiles Technology area seeks to develop and transition the technologies necessary to provide capabilities to take advantage of

opportunities and overcome the challenges posed by the Future Joint Warfighting Capabilities. These capabilities include: assisting in the collection, management, dissemination, and exploitation of information, including defending our information systems and disabling an adversary's; the evolutionary upgrading of all military systems across the spectrum of conflict, indicating a need to stay abreast of a broad spectrum of technologies; assisting in solving pervasive challenges that have a potential significant impact to the nature of war, including information access, mobility, and precision strike; aid in protecting and enhancing the effectiveness of individuals and small units through non- and counter-proliferation. Space as an operating environment offers significant and sometimes unique characteristics for addressing these challenges and opportunities. The technologies captured in the Space and Missiles Technology area seek to enable systems and improve capabilities to take advantage of those characteristics.

The Future Joint Warfighting Capabilities define the future technology needs. However, limited budgets place constraints on our S&T program and we must prioritize. Technological superiority is a primary driver of our investment decisions in our Space and Missiles Technology area. Our investment strategy is placing more priority on technologies to improve productivity and reduce cost. We leverage our efforts with industry to mutually exploit technology innovation as part of our vision for future technology development and transition. An emphasis is placed on direct commercial exploitation, assessment of commercial off-the-shelf technology for military application, and cooperative research and development.. Technology helps to ensure that the Air Force can buy more for less and increase the effectiveness of our systems. The need for affordability is a pervasive requirement that is being emphasized throughout all aspects of our Space and Missiles technology development.

The cumulative effect of the investments and efforts in the Space and Missiles Technology area on warfighter capabilities 10 and 20 years from now will be dramatic. Sensor detector, electronic, payload thermal management, payload stabilization, power generation, storage and management, and data processing and communication advances will provide the tools to develop future systems. These technologies are focused in the pursuit of making the warfighter omniscient regarding his adversaries and the battlefield. Warfighter awareness and their ability to communicate will provide the forewarning necessary to engage regional forces promptly in decisive combat. Our technology development can support the tactical deployment of high-performance communication and sensing assets by warfighters in the field which will allow near real-time collection and communication of the information to individuals and small groups.

To make deploying these capabilities in the space environment affordable, investments in component weight reduction, payload performance enhancement, on-board processing capability, and lift systems will combine to make space systems remarkably smaller and lighter, and lift systems significantly more capable and less costly. Similarly, investments in operation and control technologies will result in improvements in design, integration, and operation processes, as well as reductions in cost. While the sensors themselves may or may not be developed in this technology area, the improvements in affordability will make the deployment of sensors for detecting and identifying proliferation activities realizable from a cost perspective.

Well beyond 10 years from now, the nation's ballistic missile arsenal will still reside in the same silos they occupy today, thanks to continual component improvements made possible by investments in ballistic missile technology. Those same investments provide the nation a precision, global strike capability with minimum casualties and collateral damage thereby providing one more response option for the warfighter.

The investments made in the Space and Missiles Technology area, when combined with investments and advancements made in related technology areas, will enable advancements in our Air Force technology base. The resultant capabilities will make war faster and less deadly than war as we know it today.

"This plan has been reviewed by all Air Force laboratory commanders/directors and reflects integrated Air Force technology planning. I request Air Force Acquisition Executive approval of the plan."

Michael L. Heil

MICHAEL L. HEIL, Colonel, USAF
Commander
Phillips Laboratory

Richard R. Paul

RICHARD R. PAUL
Major General, USAF
Technology Executive Officer

CONTENTS

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INTRODUCTION

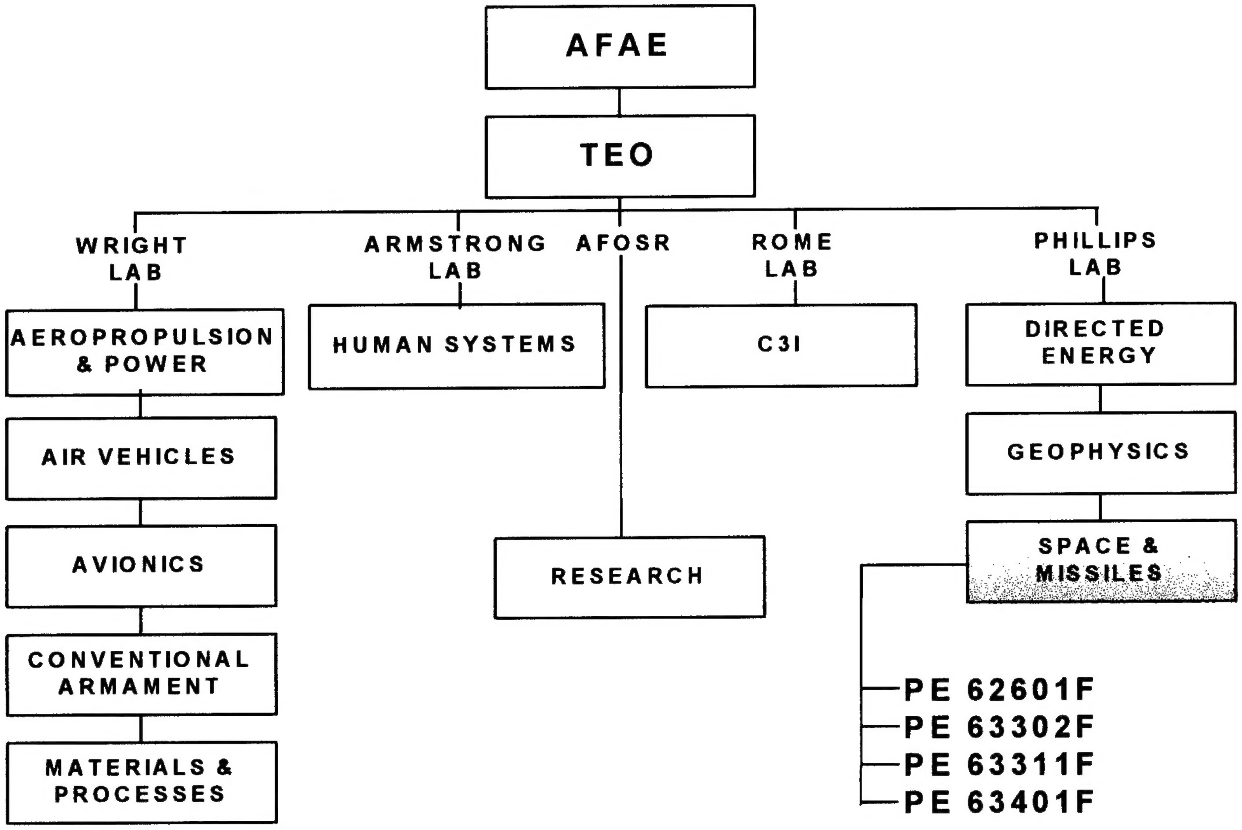


Figure 1: Air Force S&T Program

BACKGROUND

The Space and Missiles Technology Area is that part of the Air Force Science and Technology (S&T) Program charged with developing evolutionary and revolutionary technology for spacecraft and missile systems. The validated MAJCOM requirements are in Mission Need Statements, Operational Requirements Documents, and Mission Area Plan (MAP) Deficiencies. Product Divisions generate technology requirements to support advanced systems.

These near and far term requirements of the space and missile community are inserted into various Technical Planning Integrated Product Teams (TPIPT) which develop integrated requirements, system, and Space and Missile Science Technology roadmaps.

We coordinate and align the programming reflected in this Technology Area Plan (TAP) with the TPIPTs to address user requirements and provide visionary opportunities for technology push. Both enable substantial payoffs for AF systems.

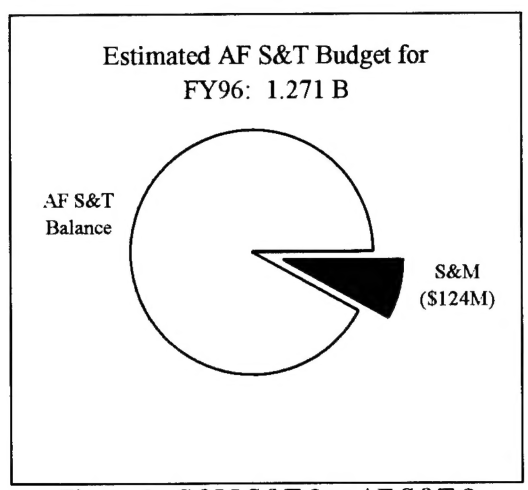


Figure 2: S&M S&T $ vs AF S&T $

We describe the programmatic implementation of our lab vision in this document to include needs, goals, major accomplishments, and changes from last year.

The Phillips Laboratory (PL) conducts a wide range of in-house and contractual programs. The total PL S&T funding reflected in the President's FY97 Budget Request to perform basic research, exploratory development, and advanced technology development for the Space and Missiles Technology Area approaches $124 million (ref. Fig 2). The program described in this TAP is subject to change based on possible Congressional action.

Along with AF S&T, PL conducts programs funded by other sources. Ballistic Missile Defense Organization (BMDO) is the major source of funding.

Advanced Research Projects Agency (ARPA) and NASA provide significant funding to PL for complementary Space and Missile S&T.

We manage the technology efforts in the Space and Missiles TAP along the following eight technology thrusts to meet AF and DoD needs:

1. **Boost and Orbit Transfer Propulsion Technology**
2. **Tactical and Spacecraft Propulsion Technology**
3. **Space Vehicle Structures and Control**
4. **Advanced Space Technology Integration and Demonstration**
5. **Space Power and Thermal Management**
6. **Space Sensors and Satellite Communications**
7. **Space Vehicle Electronics and Satellite Control**
8. **Space Vehicle and Missile Dynamics Technology**

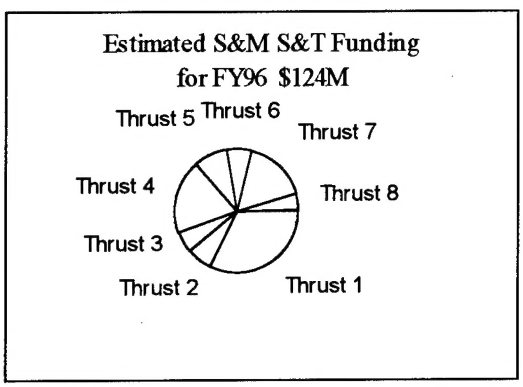


Figure 3: Thrust Funding Split

The following are recent accomplishments in Space and Missile Technologies:

A high power (30 kW) ammonia arcjet propulsion system for orbit transfer was flight qualified for integration into the SMC "ARGOS" space test vehicle. This system will be launched on ARGOS in FY97 to validate high power electric propulsion orbit transfer capabilities.

High Energy Density Material (HEDM) programs began testing and evaluating downselected propellant candidates for transition into future, high performance boost and orbit transfer propulsion systems. HEDM programs also test fired a cryogenic hybrid rocket using oxygen and a cryogenic hydrocarbon, demonstrating performance increases over current liquid systems.

Hydrostatic bearings are being integrated into oxygen and hydrogen rocket turbopumps. These bearings have no touching metal surfaces during steady state conditions which result in no wear, highly reliable engine bearings, increasing liquid booster propulsion performance.

Testing and demonstrations were completed for environmental propellants and processes that produced minimal smoke and environmentally safe tactical missiles with components that improve missile thrust and reduced plume signatures.

Successfully demonstrated advanced system identification methods for development of global, active structural control systems. Initiated program with Composite Optics Inc. to design and fabricate composite spacecraft bus structure for MightySat program.

The Technology for Autonomous Operational Survivability (TAOS) integrated space flight demonstration was launched in March 94 from Vandenberg AFB. Phillips Laboratory has worked for the past two years with Mission Control teams from Onizuka AFB and Cheyenne Mountain AFB on TAOS experiments. This enormously successful mission, lasting far beyond the spacecraft's expected lifetime, will continue into FY97.

PL established a three phase program with Navy, Sandia National Laboratories, and the AF to develop sodium sulfur battery technologies for space power applications. The lab conducted extensive safety and abuse testing along with life cycle evaluation.

Demonstrated, for the first time, proof-of-principle design models of high reliability cryogenic cooler concepts (pulse tube, stirling, and turbo Brayton) in support of user requirements at 35, 60, and 65K.

Results from the long-wavelength HgCdTe detector improvement task and the related effort on defect reduction at WL/ML enabled fabrication of the highest performance detectors ever demonstrated. We demonstrated an innovative lateral collection device architecture (under CRDA with Aerojet Corp) that will allow longer cutoff wavelength HgCdTe detectors and could potentially reduce effects of material defects on device performance. Novel multiband, voltage tunable, quantum well detector was demonstrated. Developed new theoretical models that predict correct temperature dependence of peak absorption. of QWIP devices. Demonstrated use of commercial foundries for fabrication of cryogenic readouts with low radiation hardness requirements.

We continue to identify, develop and transition key technologies in Active Sensors for affordable, non-deniable, broad area, all-weather surveillance systems supporting Global Reach/Global Power. These key technologies areas include: developing Advanced Onboard Processing & Control technologies; developing large, lightweight, multi-mode/band/phenomenology antennas; and developing sensor characterization modeling and simulation capabilities. A major emphasis during the past year resulted in defining an experiment to be conducted in FY96 on a radar detection algorithm called "Have Gaze" to step beyond phenomenology exploration and determine its usability in many radar background environments.

At the request of the MILSATCOM Program Office, we initiated efforts to mature technologies for MILSATCOM payloads and satellite buses. These efforts will drastically reduce the weight of future space communication systems, allowing launches on medium launch vehicles and possibly saving tens of millions' dollars. Rome Laboratory is also a key player in the MILSATCOM program in the areas of communications, antennas, EHF processing, and multi-chip modules.

We applied radiation hardening design practices to develop a gate array on a commercial fabrication line which has 10 times more hardness than standard circuits.

We completed the radiation hardening of 32-Bit RISC processor by modifying the design to incorporate single-event hardened latches; demonstrated prototype devices.

We developed the first radiation hardened 800K field programmable gate array by improving and transferring a widely used commercial design to a space foundry.

PL installed the first Multimission Advanced Ground Intelligent Control (MAGIC) system at Falcon AFB Space Operations Complex (SOC) 33. This provides telemetry storage and analysis for operational life of satellites managed by SOC 33. MAGIC proved the concept of a low cost, flexible satellite control architecture.

We had a successful flight of the Missile Technology Demonstration 1 (MTD 1) on 16 August 1995. MTD-1 consisted of a US Army STORM ballistic missile with a modified Pershing II reentry vehicle. The flight provided new empirical data for an 284 lb class penetrator into a geology of interest. A commercial differential GPS/INS package gave extremely accurate range metrics and position information and enabled the impact point to be estimated continuously for an on-board autonomous range safety solution. A Counter Measures Hands-on Program (CHOP) piggy back experiment was also successfully flown. These experiments will result in improvements in range safety and metrics for all space and missile flights. For example, White Sands Missile Range has already incorporated results from MTD-1 into their radar modeling for increased accuracy.

RELATIONSHIP TO OTHER TECHNOLOGY PROGRAMS

The Space and Missiles Technology Area is broad based and supports many AF mission areas. These complementary relationships permit maximum leverage of the R&D investment.

The Air Force Office of Scientific Research (AFOSR) supports numerous PL basic research efforts. AFOSR chemical science supported energetic materials research flows directly to the Applied Research In Energy Storage (ARIES) program efforts investigating HEDM. Aerospace science research feeds investigations of combustion mechanisms, plume phenomena, and plasma diagnostics. It supports research in basic understanding of composite materials bonding and fracture mechanics. Spacecraft initiatives benefit from basic research in spacecraft dynamics and control phenomena as well as Project Forecast II-derived research on HEDM synthesis.

Wright Laboratory (WL) provides manufacturing and materials technology development for several thrusts. Manufacturing Technology (MANTECH) provides methodologies for scaling research materials into production quantities. Selected propulsion technology components have been carried from exploratory through advanced development and become candidates for MANTECH demonstrations. The Materials Technology Area (WL/ML) develops materials and processes for lightweight structural applications; high temperature rocket engines and thermal protection; sensors and communication and survivability from laser threats. In a partnership with PL, WL/ML acts much like a PL directorate, where WL/ML transitions materials technologies to support PL satellite, launch, and propulsion technologies. Additional cooperative efforts exist with our thrust axis accelerometer, precision fiber optic gyroscope and micro-inertial instruments programs.

Rome Laboratory (RL) and WL provide 6.1 and 6.2 technology programs in the area of antennas, component reliability, software, photonics, communications, and signal processing. We transition these to PL 6.2 and 6.3 technology efforts. We will continue to coordinate with RL to meet AF Space and Missile technology needs.

PL develops space power technologies for primary and secondary systems with a joint government and industry team. Lithium ion battery technology is being developed in close coordination with WL and other AF agencies. NASA is supporting the development of both nickel hydrogen IPV and CPV designs. The primary battery program is strongly supported by Lockheed Martin for insertion into their launch vehicles.

The space environment (plasma, radiation, thermal gradients) negatively effects solar cells, batteries and power system electronics. Through joint flight experiments (like PASP+) with the Geophysics Directorate, we incorporate understanding of these effects in our power system development.

We actively coordinate ultraviolet sensor and component characterization activities and environmental modeling with the Geophysics TAP. Our work supports the Advanced Weapons TAP by assisting in development of Infrared sensors for the Maui and STARFIRE Optical Range. We work antenna and EHF component development efforts collaboratively within the C^3I TAP. We joined with the MILSATCOM Program Office to develop technologies for Advanced MILSATCOM payloads for FY96 and beyond. In the active sensors area, we began work on folding the various databases being developed on radar clutter backgrounds into a usable tool for modeling signal processing algorithms. This included major technology efforts at Lincoln Labs, NASA (under the SIR-C and XSAR shuttle programs), and at Georgia Tech Research Institute.

BMDO provides considerable resources focused on kinetic energy weapons and plume phenomenology. We are developing small, modular satellites, Advanced Liquid Axial Stage, and Advanced Solid Axial Stage propulsion systems for BMDO missions. BMDO has been supporting adaptive structure technology development and precision pointing experiments.

The Advanced Research Projects Agency (ARPA) sponsors downlink EHF antenna technology and GPS Guidance Package efforts.

PL is working with NASA Goddard Space Flight Center to develop high-density memory modules for two satellite programs. We will produce space-qualified single-layer modules and multi-layer modules next year. Joint data collection efforts using NASA/JPL SIR-C/X-SAR and TOPSAT are critical to AF active sensor work.

PL is a member of the Space Technology Interagency Group (STIG) Information Processing Committee, coordinating programs with Rome Laboratory, NASA, Wright Laboratory and the other Services in Communications, Sensors, and Processing and Electronics. A LASERCOM working group has been established with US government agencies.

Our modeling and simulation (M&S) efforts support the Army's obscurants modeling and transporter - erector - launcher live simulator development, and the Naval Postgraduate School's Unmanned Aerial Flight Simulator. Passive sensor efforts address deficiencies in the Army's USASSDC sensor packaging program.

European Space Agency (ESA) Infrared Space Observatory Spectrometer used detector technology developed by PL. We continue to develop detector material technology with international partners.

We are working with the Army, Navy, and other Air Force agencies in a joint effort to support the Hardened and Deeply Buried Targets (HDBT) ACC/STRATCOM Mission Need Statement. PL will host the industrial concept presentation day and integrate HDBT needs into its Ballistic Missile Technology efforts.

CHANGES FROM LAST YEAR

DDR&E is leading an effort to plan DoD S&T efforts called the Technology Development Approach (TDA). It is a framework for organizing and guiding S&T investments in the government, industry and academia. Thrusts 1 and 2 became involved in this effort two years ago in the IHPRPT program, while the rest of the Space & Missiles TAP started the process this year. By developing technology objectives, subsystem goals, and system payoffs, our programs can be focused on the highest payoff efforts and transitioned to industry when they are needed.

A three-tiered program to provide a full-service, integrated set of complementary demonstration capabilities has been initiated. Services range from ground-based "hardware-in-the-loop" experiments to technology flight experiments such as MightySat or balloon programs to integrate space flight demonstrations.).

Our only nuclear effort (TOPAZ) transferred to the Defense Nuclear Agency as of 1 Jan 96.

Congressional restrictions for advanced space communications work in PE 63401 Project 3784 were relaxed for FY96. Active Sensors saw a dramatic increase in attention on Space Based Theater Surveillance during the year. While reviewing the Have Gaze signal processing algorithm, the Defense Science Board requested a more definitive concept on which this algorithm might be used as a primary or adjunct mode. We were involved in an Air Force directed Space Sensors study to look at replacing AWACS, JSTARS, and Rivet Joint. The study concluded that insufficient technology base was present in two areas, space power and space lift, to make a meaningful decision before FY00. PL will address this in our future planning and budgeting cycles.

In cooperation with ARPA, we initiated a program to study applications for Microelectromechanical Systems (MEMS) for space. This program will include development of space-unique technologies to apply this promising technology.

Congressional language required Advanced Guidance and Reentry Vehicles be extensively modified. Sufficient funds were added to move Missile Technology Demonstration II (MTD II) forward so that money will be available to finance the flight in FY96. Data from this flight will now directly impact AFSPC's ACTD in FY98.

THRUST 1: BOOST AND ORBIT TRANSFER PROPULSION TECHNOLOGY

USER NEEDS

The Air Force Policy of "Global Presence" cites Situational Awareness and Strategic Agility as tenants needing "technological innovations" to "enhance US ability to exert presence." The following SMC Development Plans and NASA requirements demand propulsion improvements to fulfill critical deficiencies:

SPACELIFT - High Performance, Advanced, Cryogenic and Liquid Rocket Propellants and Engines, Low Cost Solid and Hybrid Motors, Low Cost Manufacturing, High Performance Low Cost Expendable Engines, Solar Thermal Propulsion (for Orbit Transfer), Advanced Orbit Transfer Concepts, and Manufacturing Technologies

GLOBAL DETERRENCE - Motor Aging and Surveillance

CONVENTIONAL DETERRENCE - Missile Propulsion Material Applications, Global Range and Survivability, Missile Propulsion Technology, Missile Propellant Non-Destructive Test Technology, Solid Rocket Motor Manufacturing, Reliability

RECONNAISSANCE/SURVEILLANCE - Large Payload Spacelift Systems

NASA - Advanced Reusable Spacelift, Low Cost Reliable Access to Space.

GOALS

The propulsion needs identified above will be fulfilled by achieving the goals set forth in the Integrated High Payoff Rocket Propulsion Technology (IHPRPT) initiative. IHPRPT's vision is to double spacelift propulsion capability by 2010 through the development of advanced, innovative rocket propulsion technology.

By 2000, the IHPRPT spacelift goals will:

- increase expendable payload to orbit capability by 9% or reusable payload to orbit capability by 71% (over the life of the reusable system) and
- reduce payload launch costs by 19%.

By 2000, the IHPRPT orbit transfer goals will:

- double repositioning capabilities (double number of repositioning maneuvers) or
- increase allowable satellite mass by 10%.

By 2010, the IHPRPT spacelift goals will:

- increase expendable payload to orbit capability by 22% or reusable payload to orbit capability by 206% (over the life of the reusable system) and
- reduce payload launch costs by 42%.

By 2010, the IHPRPT orbit transfer goals will:

- increase repositioning capability by 5 times or
- increase allowable satellite mass by 30%.

To do this, liquid, solid and hybrid spacelift development is crucial. Chemical, and solar orbit transfer propulsion development is also critical to achieve the necessary mission improvements. Chemical and solar thermal orbit transfer propulsion system improvements will be targeted toward increased propulsion system performance. Anticipated decreases in satellite propulsion system weight and size will provide additional cost reductions.

In response to the above needs, PL develops technology for:

- high performance, low cost expendable propulsion
- advanced liquid and cryogenic reusable and expendable propulsion
- orbit transfer propulsion
- low cost, rapid prototype thrust cell and component manufacturing technology
- high energy materials for potential use as propellants
- improved ballistic missile motor service life in both existing and new systems and
- reduced manufacturing and support costs.

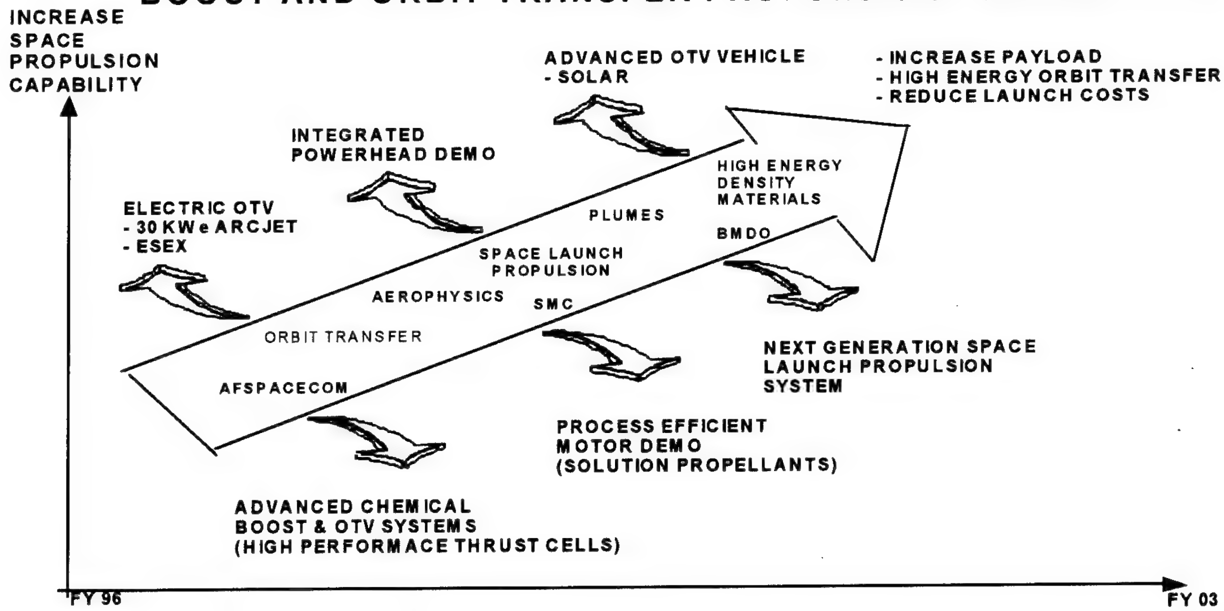
In addition, we must:

- develop motor manufacturing processes that eliminate harmful chemicals used in rocket motor manufacturing
- develop long life, high performance, environmentally acceptable solid propellants while maintaining properties/integrity equal to current solid propellants
- develop motor components capable of withstanding the increased temperatures created by new environmental propellants.

These technologies will provide the technical solutions to develop next generation space systems in addition to upgrades for existing space vehicles. The major challenges to achieving the spacelift goals are addressed by our programs which:

- apply advanced materials to increase the life and decrease the weight of components
- integrate health management sensors in the design of components eliminating the high cost of retrofitting these sensors
- investigate combustion technology and improve current engine designs to make stable, reliable, low cost propulsion engines for boost and orbit transfer

THRUST 1
BOOST AND ORBIT TRANSFER PROPULSION TECHNOLOGY



- coordinate our efforts closely with the Navy, Army, NASA, and Industry to lower development costs for everyone involved.

IHPRPT is based on cooperative efforts with Army, Navy, NASA, AF, and all US propulsion companies.

MAJOR ACCOMPLISHMENTS

A high power (30 kW) ammonia arcjet propulsion system for orbit transfer was flight qualified for integration into the SMC "ARGOS" space test vehicle. This system was to be launched on ARGOS in FY96 to validate high power electric propulsion orbit transfer capabilities, but the launch date was postponed and is scheduled to be launched in FY97.

The High Energy Density Material (HEDM) programs began testing and evaluating downselected propellant candidates to transition into future, high performance boost and orbit transfer propulsion systems. HEDM programs also test fired a cryogenic hybrid rocket using oxygen and a cryogenic hydrocarbon, demonstrating performance increases over current liquid systems. Large scale quadricyclane engine tests/demonstrations with new additives were also performed.

Hydrostatic bearings are being integrated into oxygen and hydrogen rocket turbopumps. These bearings have no touching metal surfaces during steady state conditions which result in no wear, highly reliable engine bearings, increasing liquid booster propulsion performance. The design and fabrication of a complete thrust chamber with extended thermal-cycle life, decreased system costs, and increased liquid engine reliability was accomplished which will be used in boost and orbit transfer missions. Preburner and turbopump designs were reviewed and approved for the integrated powerhead demo. Fabricated the preburner with final turbopump fabrication to be done FY97.

CHANGES FROM LAST YEAR

In FY96, Thrust 1 consisted of Missile Propulsion which included tactical and strategic missile propulsion. Thrust 2 consisted of Space Propulsion which included solid, liquid, and hybrid space launch propulsion and all OTV and satellite propulsion development.

FY97 changes Thrust 1 to boost and orbit transfer propulsion encompassing strategic and space boost systems and chemical and non-chemical orbit transfer systems. Thrust 2 is now spacecraft and tactical propulsion systems encompassing satellite repositioning and stationkeeping propulsion and tactical missile propulsion.

Milestones	Year	Metrics
Develop/Demo low cost thrust cell fabrication technology	FY97	Prove rapid prototyping techniques and 60% cost reduction
Develop/test injector design codes	FY97	Validate injector design codes
Demo ammonia arcjet propulsion OTV	FY97	Demo 30 kW spacecraft arcjet propulsion OTV with doubled repositioning capability over current systems
Demo integrated powerhead (IPD) preburner/turbomachinery	FY98	Test IPD engine conditions. Quantify performance, operability, and reliability improvements
Develop/test altitude compensating nozzle design	FY99	Show 15% increase in flight trajectory performance

THRUST 2: TACTICAL AND SPACECRAFT PROPULSION TECHNOLOGY

USER NEEDS

The Air Force Policy of "Global Presence" cites Situational Awareness, Strategic Agility and Lethality as tenants needing "technological innovations" to "enhance US ability to exert presence." The following SMC/AFSPC, ACC and NASA Development Plans also require propulsion improvements to fulfill critical deficiencies:

MISSILE OFFENSE, AIR TO SURFACE, and COUNTERAIR - Motor Service Life Prediction and Extension, High Performance Environmentally Acceptable Propellants, Low Cost Environmentally Acceptable Manufacturing Processes

CONVENTIONAL DETERRENCE - Missile Propulsion Material Applications, Global Range and Survivability, Missile Propulsion Technology, Missile Propellant Non-Destructive Test Technology, Solid Rocket Motor Manufacturing, Reliability

RECONNAISSANCE/SURVEILLANCE - Cost and Survivability, Prompt Response without Force Deployment , Long Range Strike Capability

COUNTERSPACE, MISSILE WARNING - Survivability

MISSILE DEFENSE - Survivability, Propellant Development

NON-SPACE - Fast Reaction Tactical Missiles, Less Time to Target, Increased Range, Throttle on Demand, Low Cost, Increased Environmental Compliance.

SATELLITE - Advanced Propulsion/Power Conversion for Electric Propulsion (for Stationkeeping/Maneuvering)

WEATHER - Small Satellite Technology

NAVIGATION - Modernization of Current Systems, Upgraded Future Systems to Replace Current Systems with Lower Power Consumption, Improved Power Conversion, Advanced Attitude Control, Advanced Electric Propulsion and Solar Propulsion.

GOALS

The propulsion needs identified above will be fulfilled by achieving the goals set forth in the Integrated High Payoff Rocket Propulsion Technology (IHPRPT) initiative. IHPRPT's vision is to double solid rocket propulsion capability by 2010 through the development of advanced, innovative rocket propulsion technology.

By 2000, the IHPRPT tactical goals will:

- increase either warhead payload or range by 10%.
- reduce the number of theater missile defense systems needed to cover an area by 26% for divert (steering control) propulsion systems.

By 2010, the IHPRPT tactical goals will:

- double tactical warhead payload or range and, reduce necessary theater missile defense systems for divert propulsion by 60%.

By 2000, satellite propulsion systems will:

- extend their life in geosynchronous orbit (GEO) by 25%
- double repositioning capabilities (number of repositioning maneuvers) or
- increase allowable satellite mass by 10% with present life span capabilities.

By 2010, satellite propulsion systems will:

- extend their life in GEO by 45%
- increase repositioning capability by 5 times or
- increase allowable satellite mass by 30% with present life span capabilities.

To accomplish these tactical payoffs, solid propellant and motor component development is crucial. The Phillips Lab (PL) rocket propulsion directorate has the only programs which develop solid rocket propulsion technology for all Air Force tactical missile systems.

Our tactical propulsion efforts initiated in FY94 have been coordinated with the NAVY under the Project RELIANCE agreement. We are working together to satisfy the range, survivability, and rapid response deficiencies stated above by:

- developing light weight tactical rocket components to allow for increased warhead carriage capability or increased range.

Our polymer material programs focus on:

- developing longer life, stronger motor components.

Production costs of insulation and nozzles will decrease by as much as 40%. Large payoffs in other component processing programs like our carbon densification and lightweight coatings are:

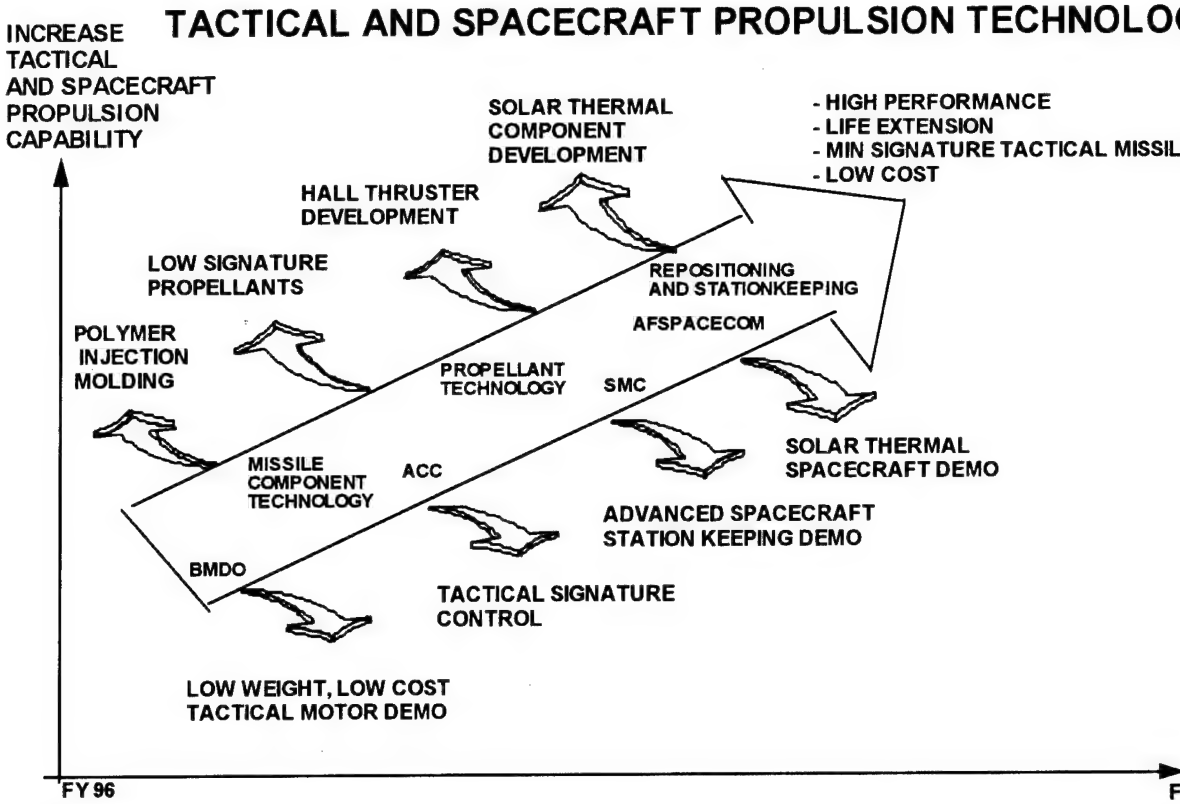
- cutting production time and costs,
- decreasing nozzle erosion rates (which increase reliability, performance, and range) and
- increasing oxidation resistance (which also increase reliability).

Our carbon composite and coatings programs also have significant dual use opportunities and provide similar payoffs to the solid space systems cited in Thrust 1.

Solar electric and solar thermal spacecraft propulsion development is also critical to achieve the satellite improvements for stationkeeping and maneuvering. Extraordinary increases in maneuvering and stationkeeping capabilities are anticipated through the improvements in solar satellite propulsion systems. Spacecraft propulsion developments in:

- pulsed plasma thrusters,

THRUST 2
TACTICAL AND SPACECRAFT PROPULSION TECHNOLOGY



- anode layer thrusters, and
- solar thermal (laser thermal) systems

will be investigated (in conjunction with NASA) to achieve the above payoffs.

MAJOR ACCOMPLISHMENTS

Testing and demonstrations were completed for environmental propellants and processes that produced minimal smoke and environmentally safe tactical missiles with components that improve missile thrust.

Our satellite propulsion programs designed a high altitude balloon experiment for demonstration of an improved solar thermal thruster. The results of this balloon experiment feed into a solar thermal propulsion system demo in 2005. We also optimized the internal magnetic field for the 1000-watt anode layer thruster.

CHANGES FROM LAST YEAR

In FY96, Thrust 1 consisted of Missile Propulsion which included tactical and strategic missile propulsion. Thrust 2 consisted of Space Propulsion which included solid, liquid, and hybrid space launch propulsion and all OTV and satellite propulsion development.

FY97 changes Thrust 1 to boost and orbit transfer propulsion encompassing strategic and space boost systems and chemical and non-chemical orbit transfer systems. Thrust 2 is now spacecraft and tactical propulsion systems encompassing satellite repositioning and stationkeeping propulsion and tactical missile propulsion.

Milestones	Year	Metrics
Integrate components and propellant into tactical sized motor	FY97	Demonstrate 10% increase in mass fraction and 7% increase in delivered energy
Adapt C/C rapid densification technique to nozzle fabrication	FY97	Fire high density low erosion rocket motor nozzles
Design high altitude balloon experiment for improved solar thruster	FY97	Validate high altitude balloon experiment
Develop anode layer thruster (ALT)	FY98	Demonstrate 15% increase in mass fraction and 15% increase in thruster efficiency
Fabricate high altitude balloon experiment for improved solar thruster	FY99	Demonstrate 10% increase in Isp and 15% increase in mass fraction

THRUST 3: SPACE VEHICLE STRUCTURES AND CONTROLS

USER NEEDS

Many SMC Development Plans identify several structures technologies as critical to meeting AFSPC Mission Area Plan deficiencies. These include:

SPACELIFT - Low -Cost Structures/Tanks/Fairings; Lightweight, Operable Smart Structures, Conformal Tanks (RLV), Integral Tanks/Structure/TPS; Launch Vehicle Isolation System; Lightweight Structures

MISSILE WARNING -Lightweight Structure, Lightweight Antenna; Acquisition, Tracking and Pointing Development

NATIONAL MISSILE DEFENSE - Beam Generator Isolation from Expansion and Pointing Optics

SATCOM -, Lightweight Antenna

NAVIGATION - Lightweight Structures; Lightweight, Low Cost Arrays

INTELLIGENCE, SURVEILLANCE AND RECONNAISSANCE - Lighter, Rigid, "Packable" Structures; Deployment Mechanisms

SPACE BASED ENVIRONMENTAL MONITORING - Lightweight Antennas

GOALS

The structures area has two primary technology sub-areas: Advanced Structural Components (ASC) and Structural Control & Vibration Damping (SCVD). Goals/time frame for each of the sub-areas follows:

Baseline for our goals is the 1996 current state of the art:

<u>ASC (Advanced Structural Components)</u>

- For satellites, the structural subsystem averages 20% of mass and 13% of cost
- For launch vehicles, the structural subsystem averages less than 14% of the overall mass and 30% of cost

<u>SCVD (Structural Control & Vibration Damping)</u>

- Subsystems requiring precision pointing are hardmounted to satellites and must live with spacecraft disturbances as part of their error budget resulting in degraded performance. On a case by case basis, attempts have been made to passively isolate either the disturbance source or the payload
- For large space-based laser systems, PL demonstrated 1000:1 disturbance attenuation using system level isolation between the telescope and the laser and 100:1 improvement in farfield line of sight using active structural control of the telescope
- Satellites launched on MLVs such as Delta II are subjected to pseudo-static loads $\pm$ 2.5 gs (axial) and dynamic loads of $\pm$ 3.0 gs (lateral) and $\pm$ 0.6 gs (axial) at the separation plane during launch and must be designed to survive these loads

Our near term goals for 2001 are:

<u>ASC</u>

- Reduce satellite structural mass by 40% and reduce cost by more than 10%
- Reduce launch vehicle structural subsystem cost by 25%

<u>SCVD</u>

- Decrease dynamic launch loads to which a satellite is subjected by a factor of 5
- Reduce pyrotechnic-shock to which satellites are subjected by more than two orders of magnitude
- Decrease on-orbit disturbances experienced by payloads by a factor of 10

The far term goals for 2011 are:

<u>ASC</u>

- Reduce satellite structural mass by 75% and reduce cost by more than 25%
- Reduce launch vehicle structural subsystem cost by a factor of 10

<u>SCVD</u>

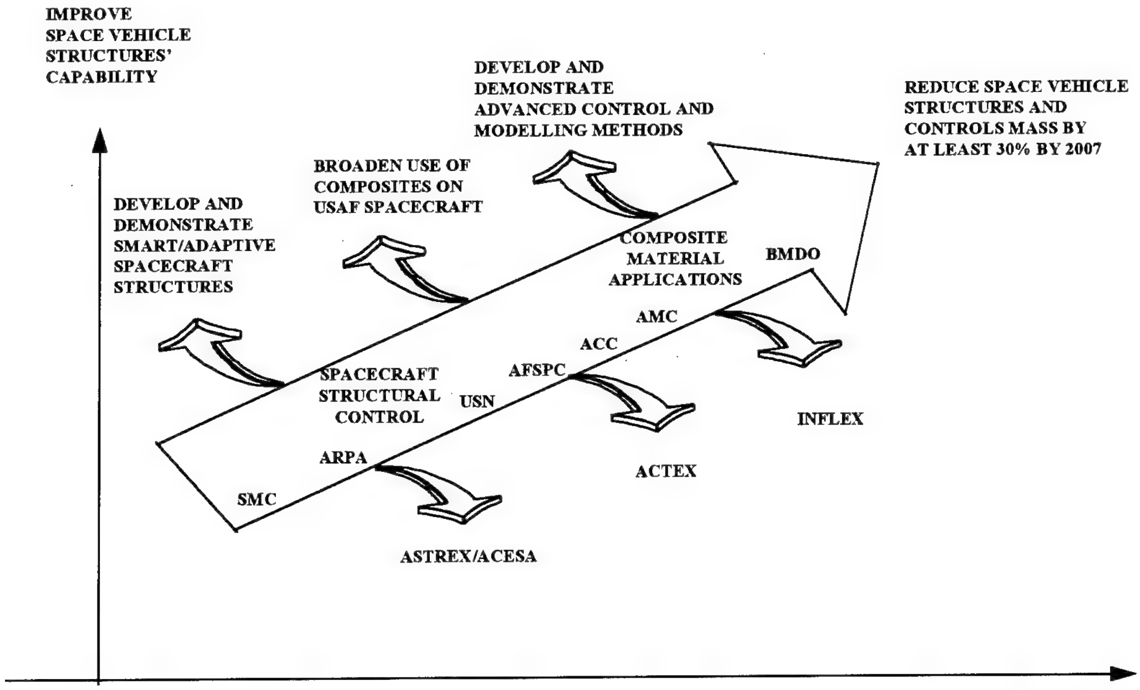
- Decrease dynamic launch loads to which a satellite is subjected by a factor of 20
- Decrease on-orbit disturbances experienced by payloads by a factor of 100

MAJOR ACCOMPLISHMENTS

Successfully demonstrated advanced system identification methods for development of global, active structural control systems. The control system, based exclusively on an experimentally derived dynamics model and implemented on the Space Integrated Controls Experiment structure, achieved a 90:1 improvement in the far field RMS line of sight error. System identification is an experimental method for developing a representative system dynamics model in terms of the input/output relationships between the control system sensors and actuators. This achievement represents the first time an experimentally-based, modern digital control system has achieved greater than 10:1 performance on a large structure. In addition, a modified version of the original, analytical model-based active control system achieved 120:1 improvement in the far field RMS line of sight error; it is believed that the experimentally-based control system could have achieved similar performance with further optimization. The system identification process is the first step in developing an autonomous active structural control system capable of adapting to changes in environment or changes in system characteristics.

Initiated program with Composite Optics Inc. (COI) to design and fabricate composite spacecraft bus structure for MightySat program using XSAT design as a basis. COI will employ use of their SNAPSAT fabrication

THRUST 3
SPACE VEHICLE STRUCTURES AND CONTROLS



technique, which is similar to model airplane building, as their manufacturing method. Program promises 50% decrease in weight and 30% decrease in fabrication time.

Completed research based on Russian studies which claimed that orientation of composite matrix molecules in an electro-magnetic field during cure would increase cured strengths. While Russian research has shown that partially cured systems showed a strength increase, our program was able to fully demonstrate that there is so much molecular movement at end of cure cycle that the field strengths required to affect fully cured properties are not economical.

The first experiments in our recently constructed space environment ground simulation facility resulted in a major discovery. In looking at the effect of bombarding space structural materials simultaneously with atomic oxygen in the presence of a 20 KeV electron beam, we reconfirmed that synergistic interaction of the electron beam produced more than an order of magnitude increase in the atomic oxygen erosion rate of composite material bombarded. We discovered that electrostatic charge on the structural material (instead of electron beam) also increases erosion rate with voltage of the charge. We theorized that the measured increase is due to alignment of bonding orbitals of oxygen atoms with bonding orbitals of surface atoms of the composite due to imposition of electrostatic field. The importance of this finding is that spacecraft charging, a well known problem for integrated circuit failure from discharging, can also be responsible for an increase in spacecraft erosion rates of more than an order of magnitude.

CHANGES FROM LAST YEAR

Completed construction of new Space Structure Lab at Kirtland AFB, allowing for consolidation of operations from 8 buildings at Kirtland and Edwards AFB into one building in FY95. Enabled movement of all personnel from other locations into new lab in FY 96.

Air Force 6.3 funding for both Advanced Spacecraft Structures & Controls (under PE 63401F) and for Advanced Launch Vehicle Structures (under PE 63302F) was initiated in FY96. AFOSR began funding in-house basic research work on the effect of the spacecraft environment on structure.

MILESTONES	YEAR	METRICS
Flight Test of Shape Memory Alloy Release Device	FY97	Successful Demonstration of Performance Requirements
Prototype Fabrication and Testing of Smart Mechanisms	FY97	Demonstrate 30% reduction in cost, 50% savings in power, and 40% decrease in weight
Optical Precision Platform Experiment Flight Test	FY99	Demonstrate on-orbit 100 times isolation of satellite disturbances

THRUST 4: ADVANCED SPACE TECHNOLOGY INTEGRATION AND DEMONSTRATION

USER NEEDS

Air Force Space Command (AFSPC) has a critical need to develop standardized, affordable, and more efficient space system designs and operational practices to meet the needs of the warfighter beyond the year 2000. AFSPC needs and deficiencies are identified through the use of AFSPC Mission Area Plans (MAPs) and Space and Missile Systems Center (SMC) Technology Planning Integrated Product Teams (TPIPTs). The critical step in providing the required emerging technologies which address the needs and deficiencies identified in this process is orderly and routine space, near-space, and ground demonstrations conducted in a timely manner. We will meet this need by validating laboratory and ground tests through space, near-space, or ground demonstrations of new systems. By planning regular scheduled demonstrations, fast and efficient technology transition will be available to meet the user needs with confidence. By combining new technologies into mission oriented demonstrations, improvements in operations and tactics can also be demonstrated. The synergistic effect of operations, tactics, and new technologies will result in the maximum improvement in both life cycle costs and performance.

GOALS

The broad goals of the Advanced Space Technology Integration and Demonstration Thrust are to transition technology by:

- Providing integrated space flight and ground demonstrations to address AFSPC identified deficiencies and weaknesses;
- Reducing cost of developing, launching, and operating space systems; and
- Minimizing risk associated with inserting advanced technology into the operational satellites developed by SMC and operated by AFSPC.

Methods to Meet Goals:

- Validate new satellite technologies using state-of-the-art and standard satellite configurations;
- Employ simplified command and control concepts;
- Involve the user in the planning and execution of advanced technology and integrated space flight demonstrations, including development of operational strategies based on advanced technology;
- Employ autonomous satellite operations;
- Perform enabling experiments and integrated demonstrations to transition advanced space system related technologies to users;
- Verify the maturity of technology;
- Emphasize a streamlined concept of operations with maximum use of experienced integrated product teams to include contractors, in-house expertise from all PL Directorates, the Air Force Laboratories, and other government agencies;
- Provide sustaining role in improving the laboratory's integration and system engineering capability;
- Provide actual experience in design, fabrication, integration, systems engineering and flight of spacecraft payloads to personnel; and
- Integrate and execute ground, near space and space demonstrations for other DoD agencies leveraging their technology developments to enhance AF capabilities.

MAJOR ACCOMPLISHMENTS

The Technology for Autonomous Operational Survivability (TAOS) integrated space flight demonstration has continued its enormous success through FY96. The TAOS program office has planned additional experiments and extended the flight into calendar year 1997 at the request of several customers.

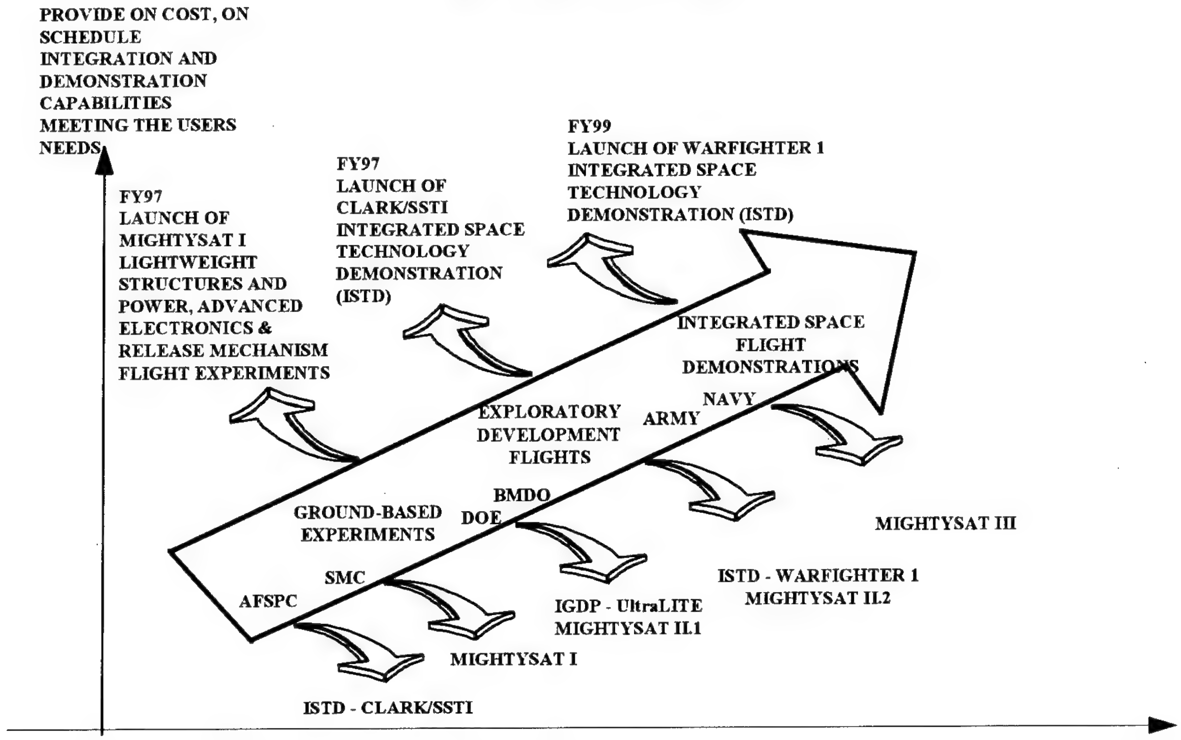
In December of 1995, Phillips Laboratory awarded a contract for the procurement of three spacecraft buses for the MightySat program. This spacecraft bus offers a greatly enhanced space experiment platform for Phillips Laboratory experimenters. Enhancements include three-axis stabilization and 250 watts of spacecraft power. Although cost to the program has increased, MightySat is still much less expensive than comparable satellites.

During FY96, Phillips Lab activated two laboratories critical to space demonstration. The Aerospace Engineering Facility is the integration site for current and planned MightySat missions, as well as numerous customer-funded flight demonstrations. The Integrated Ground Demonstrations Laboratory is the site for all ground based demonstrations including UltraLITE, our first integrated ground demonstration.

CHANGES FROM LAST YEAR

This Air Force technology thrust has historically received a disproportional amount of funding from external DoD customers (e.g. BMDO and ARPA). The decline of these budgets has forced the Phillips Laboratory to put in place an institutional program to enable continued support to our users. We now have in place a three-tiered program to provide a full-service, integrated set of complementary demonstration capabilities ranging from the Integrated Ground Demonstration Program (IGDP) "hardware-in-the-loop"

THRUST 4
ADVANCED SPACE TECHNOLOGY INTEGRATION AND DEMONSTRATION



experiments to technology flight experiments such as the MightySat programs to integrated space flight demonstrations such as the Integrated Space Technology Demonstrations (ISTD). The use of these three levels allows the Phillips Laboratory to validate emerging technologies in the most cost effective manner. Additionally, Phillips Laboratory has completed the construction of the new Aerospace Engineering Facility and renovation of the IGDP laboratory. These contractor-staffed facilities will provide the capability for hands-on integration, systems engineering, and hardware-in-the-loop simulations for such programs involving MightySat, balloons, and sounding rockets.

Another addition to our demo program this year is the Clementine II space flight experiment. The Clementine 2 mission will be carried out in conjunction with NASA. This program will test advanced surveillance, acquisition, tracking, and kill assessment hardware and software by utilizing natural space objects (near-earth asteroids) as interception targets. By concurrently gathering unique scientific data on these objects this program is fully compliant with all existing treaties. This program will test technology required for co-orbital inspection or interception of artificial or natural space objects, including potentially threatening Near Earth Objects, gathering engineering and scientific data required for the Space Control and Planetary Defense Missions.

MILESTONES	YEAR	METRICS
TAOS Data Analyses Complete	FY97	Data Analyses Complete, Mission Shutdown, Distribution of Equipment
ISTD Clark/SSTI Launch	FY97	Launch Mission; Begin On-orbit Demonstration(s); Mission Objectives Met
ISTD Warfighter 1 Integration	FY99	Design, Fabrication, Integration Complete
ISTD Warfighter 1 Launch	FY99	Launch Mission; Begin on Orbit Demos; Mission Objectives Met
MightySat I mission	FY97	Launch on Space Shuttle STS-81
MightySat II.1 mission	FY98	Launch on Space Shuttle or Multi-Service Launch System
MightySat II.2 mission	FY00	Launch on Space Shuttle or Multi-Service Launch System
UltraLITE Experiment Critical Design Review	FY97	Complete experiment design to demonstrate control capability of large aperture, sparse optical array
UltraLITE Experiment (IGDP #1)	FY99	Complete integration, execution, and analysis of a bench top experiment demonstrating capability to field a large aperture, sparse optical array
IGDP #2 Initiation	FY98	Execute systems engineering process to identify high payoff concept w/critical integration issues which will demonstrate emerging technologies

THRUST 5: SPACE POWER & THERMAL MANAGEMENT

USER NEEDS

The technology developed in this Thrust supports our Space Power and Thermal Management Planning and AFSPC Mission Area Plans which include:

MISSILE WARNING - High efficiency power, long life cryocoolers, cooling for high density electronics

SPACE SURVEILLANCE - Low cost, high efficiency power, long life cryocoolers

NAVIGATION - Long life batteries/solar cells, light weight, low cost arrays, cooling for high density electronics

MILSATCOM - High efficiency power generation and distribution

RS&I - Light weight power system, advanced power management and distribution

SPACELIFT - Advanced photovoltaic power for upper stages, thermionic power for upper stages

GOALS

Our research and development strategy emphasizes identifying and developing component technologies that have dramatic impact on total system performance. Specifically, it is our space power goal to:

- Improve total system power performance from 4 to 15 W/kg by 2005 reducing costs from \$5000 to \$3000/W.

We will pursue the following component level technology programs to meet this goal:

- High efficiency (30%) multi-junction solar cells and light weight thin film cells.
- Advanced flexible blanket and concentrator arrays with improved performance of 120 W/kg and .10m^3 stowed volume in the 1-3 kW range.
- Lithium ion and solid state battery technologies that are lower weight (50%), lower cost, less volume, and more reliable.
- Power management technologies (component and sub-system level) to reduce satellite mass while increasing modularity and satellite autonomy.

We will pursue high risk, high payoff technology programs, that if successful, promise revolutionary improvements in performance. These include:

- Non-electrochemical energy storage such as thermal energy storage, and non-photovoltaic energy conversion technologies.
- Thermionic conversion technology development necessary for a solar thermal bimodal power and propulsion system.
- High (more than 30% efficiency) energy conversion technologies for solar thermal power systems.

It is the goal of our thermal management technology programs to:

- Improve total system performance and lower life cycle costs by developing cryogenic mechanical coolers to replace cryogenic dewars and radiators . Cryocoolers operate up to 6 times longer than dewars, provide a wider range of cooling loads (0.3 through 5 Watts), and weigh an order of magnitude less than dewars or cryogenic radiators (40 lbs as opposed to 100-500 lbs).
- Reduce total thermal control system mass 15% by FY05, reduced required heater power by 35%, increase heat transport by a factor of 3 and heat flux by a factor of 2. Improvements are based upon Al/honeycomb radiator, Al thermal planes, and constant conductance heat pipes that utilize a 30 micron pore size wick.

Cryogenic cooler technology development enables cooling of infrared surveillance and missile warning payloads and superconducting electronics in the FY00-05 time frame. Our cryogenic programs will:

- Develop cryocoolers capable of operating in the 10-180K range with a 5-10 year operational lifetime.
- Develop and demonstrate cryogenic thermal control system integration technologies that eliminate significant induced vibration (1 Nrms to 0.01 Nrms) and reduce power consumption (70 W/W to 40 W/W)
- Perform extensive characterization of cryocooler performance in order to understand life limiting factors and demonstrate unit life in excess of 5 years.

Spacecraft thermal control technologies dissipate or transfer heat away from critical subsystems. We are pursuing the following technologies:

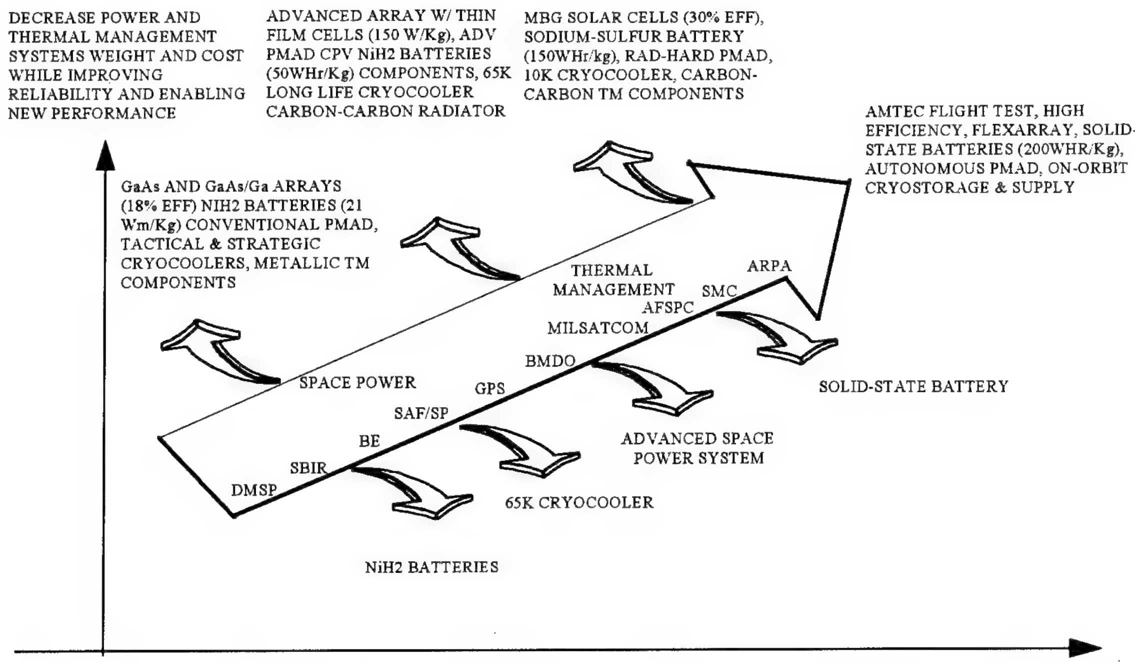
- Capillary pumped loops and flexible heat pipes capable of transporting between 14 and 200 KW-m, demonstrating up to 7 year operational lifetime, and reducing required heater power by up to 35%.
- Carbon-carbon and other advanced materials for improved heat transport and deployable radiator concepts that result in decreased thermal control system mass by 15% and high heat flux applications (up to 5 W/cm^2 at the box level).

MAJOR ACCOMPLISHMENTS

Completed two phases of sodium sulfur program demonstrating performance and safety. Limited cycle life data was generated for use of NaS in LEO and GEO orbits. The safety of sodium sulfur was verified encompassing mechanical and electrical parameters and failure modes. Phase 3 consists of an experiment scheduled to fly on the shuttle in FY97.

Completed support of manufacture and ground test of the BMDO fresnel lens concentrator array (90W/kg performance) and launched the array on the COMET satellite in August (booster terminated early in flight).

THRUST 5
SPACE POWER AND THERMAL MANAGEMENT



Accepted delivery of 22-24% efficient multijunction laboratory solar cells. Successfully led the effort for a joint PL, WL and NASA MANTECH program for the multi-junction cell which started in 1Q FY96.

Released four contracts valued at over $13M to industry to build and ground test a prototype Integrated Solar Upper Stage demonstrating bimodal power and propulsion principles. Program transitioned to the PL Launch Systems Program Office.

Continued characterization and endurance tests of engineering and protoflight, high reliability cryocoolers in support of user requirements at 35 and 60 K. Endurance tests continue on an engineering model, 5 W/65 K reverse Brayton unit. Total amount of operation exceeds 8,000 hours (approximately 1 year) of continuous operation. Continued development of a 5 W/65 K protoflight reverse Brayton protoflight cryocooler. Completed preliminary designs for the turboexpander, compressor, and heat exchanger cold end and completed fabrication of slotted plates for the heat exchanger.

Awarded contract to develop a lightweight thermal bus that incorporates deployable radiator technologies, capillary pumped loop, and high thermal conductivity composites. Initiated activity to identify and develop advanced wick technology (less than 1 micron pore size) for loop heat pipes and capillary pumped loop systems that will result in reduction of required heater power by 35% and increase the amount of heat transport by a factor of 3. Completed joint government/industry evaluation of Russian loop heat pipe technology for use on AF spacecraft. Completed development of flight experiment for high temperature Potassium heat pipe (300-600 C) to be flown on STS-77 in May 96. Initiated trade study to identify promising fiber/matrix materials for the joint industry/government effort to develop carbon-carbon composite radiator components

CHANGES FROM LAST YEAR

Our only nuclear effort (TOPAZ) transferred to the Defense Nuclear Agency as of 1 Jan 96.

MILESTONES	YEAR	METRICS
Qualify and flight test NaS battery	FY97	Tech transition 100 Whr kg NaS cells with 10 year lives
Begin development of an integrated power chip	FY98	Demonstrate modular, integrated solar cell battery PMAD system
Transition multi junction cell technology from MANTECH to industry	FY99	Mass produce cells with efficiencies between 24 - 26%
Flight test Channel Concentrator Array	FY97	Demonstrate 120W Kg, 0.10M3 arrays and transition to SMC
Ground test Solar Thermal Bimodal Power/Propulsion systems	FY98	Demonstrate OTV capability and launch vehicle stepdown
Develop and breadboard high voltage PMAD technology	FY98	Demonstrate 100v, 90% efficiency PMAD components
Flight test a pair of cryogenic flexible diode heat pipes	FY97	Demonstrate 6W @ 60 K & 20 W @ 120K
Flight test pulse tube cryocooler	FY98	Demonstrate 2.25 W at 60 K
Flight test a closed loop continuous cryogenic cooler with 10 year life	FY98	Show continuous cooling at 65 K and 140 K
Flight test a thermal storage unit at 60 K	FY98	Demonstrate 6000J with +- 0.5 K and stability @ 5 W

THRUST 6: SPACE SENSORS & SATELLITE COMMUNICATIONS

USER NEEDS

Air Force Manual 1-1 states, "American military forces have come to rely on space-based systems for instantaneous worldwide communications, constant surveillance and early warning, accurate weather forecasting, and precise navigation." Specific users operational needs and the technology required to meet them are documented in AFSPC Mission Area Plans and SMC Development Plans. Improved booster detection sensitivity and coverage and worldwide detection and tracking capability for missiles and warheads in midcourse and terminal ballistic flight are needs identified in several mission area plans:

BMD/C3 - advanced mid- and long-wavelength focal plane arrays, multicolor focal plane arrays

INTELLIGENCE SURVEILLANCE AND RECONNAISSANCE - space based theater surveillance, high performance passive sensors, hyperspectral sensors

Many AFSPC and ACC Mission Area Plans and corresponding development plans identify the need for survivable, affordable C3 capability worldwide. Lightweight, high efficiency satellite communication is a key feature of the architecture needed to provide the need for such capabilities.

Ballistic Missile Defense needs for improved sensors for boost and midcourse targets are given in Joint Chiefs of Staff Memorandum, Joint Ballistic Missile Defense Operational Requirements, USCINCSPACE Operational Requirements for Phase I Strategic Ballistic Missile Defense, JROCM 064-91 and AF MNS 004-91.

GOALS

The goal of Passive Sensors is to reduce development costs, weight, and power consumption; increase reliability, sensitivity, and resolution; and enhance affordability. This will be achieved by:

- Development of a new generation of improved, highly sensitive detectors to provide reliable missile warning by detection of dim targets, increased detection range, and improved clutter suppression.
- Development of multicolor detectors that will simplify sensor design resulting in significantly lower power requirements and lower weight.
- Develop low power infrared detector readout electronics to reduce sensor spacecraft power requirements by more than half and radiator weight by hundreds of pounds, improving the affordability and operability of space based missile warning and reconnaissance and surveillance satellites.

Our goal for Active Sensors' is to identify, develop and transition key technologies for affordable, non-deniable, broad area, all-weather surveillance systems supporting Global Reach/Global Power. Additionally, space based command and control of theater assets, using these surveillance systems will be advanced through this initiative. This will be achieved by:

- Developing Advanced Onboard Processing & Control technologies for data reduction, advanced signal processing, automatic target recognition, sensor fusion, and cross cueing, ensuring timely availability of reconnaissance and surveillance products to the tactical war fighter.
- Development of large, lightweight, multi-mode/band/ phenomenology antennas for space based military reconnaissance and surveillance missions and commercial dual-use applications.
- Developing sensor characterization modeling and simulation capabilities, including a radar clutter database for selecting alternate sensor suites and components and for driving selected technology developments from a system perspective.

Our Satellite Communications' goal is to identify, develop, and transition affordable, high data rate technologies. This will be achieved by:

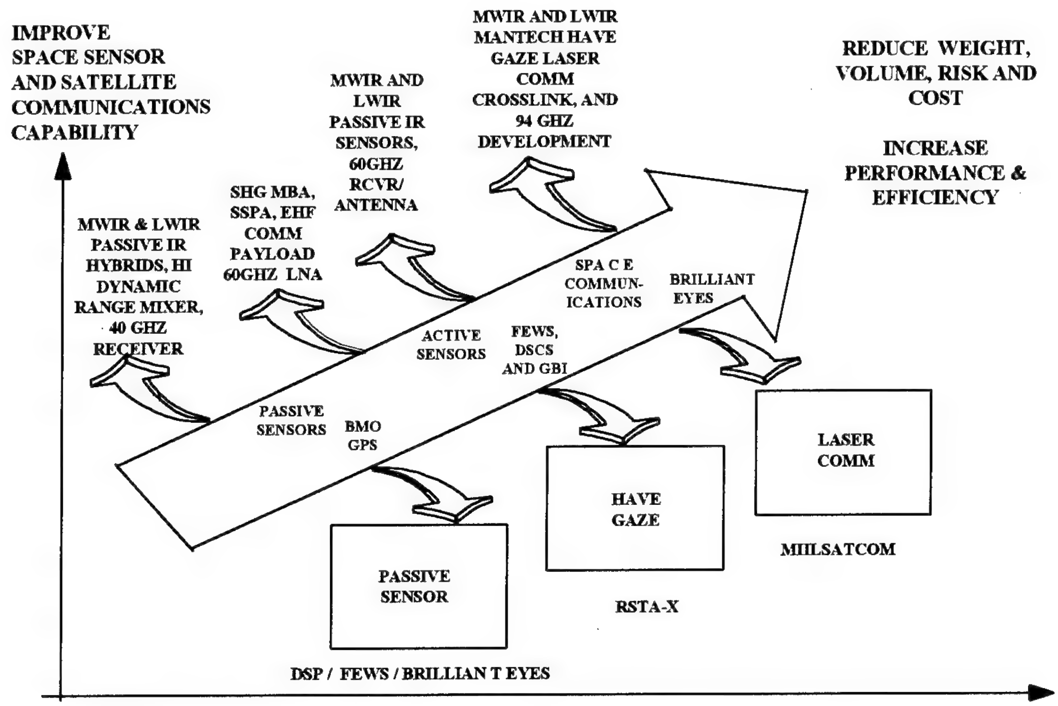
- Leveraging high efficiency, lightweight component and signal processing technology (DoD & commercial) to reduce the weight, volume and power requirements of space communication systems by more than half, making highly mobile and transportable services available to tactical forces feasible and helping provide affordable C3 capability for worldwide theater operations.

MAJOR ACCOMPLISHMENTS

Tasks to improve the performance of HgCdTe long-wavelength infrared detectors for low temperature, low background operation has been coordinated with the defect reduction program at WL/ML. It has enabled the fabrication of very high performance detectors. An effort to extend the cutoff wavelength of HgCdTe detectors using an innovative lateral collection device architecture was initiated under a CRDA with Aerojet Corp. Two lots of devices using this innovative concept were demonstrated. This new design also has the potential of reducing the effects of material defects on device performance. On quantum well (QW) devices structures were grown and evaluated under different operating conditions to determine the optimum structure for specific applications. A novel multiband, voltage tunable, detector was demonstrated. Design of QW detectors for multispectral and hyperspectral applications were addressed. Novel multispectral devices were designed, fabricated, and characterized.

In Active Sensors, inputs were made to the Defense

THRUST 6
SPACE SENSORS AND SATELLITE COMMUNICATIONS



Science Board in FY95 concerning the Have Gaze signal processing algorithm. This led to plans for a more definitive study for which Have Gaze would be consider a major adjunct capability. A synoptic study of Have Gaze under different radar clutter environments was directed out of the board. A major Air Force Space Sensor Study was commissioned for the Fall 95 Corona Study by the Chief-of-Staff. An automatic target recognition algorithm developed by Mark Resources was evaluated and determined to have large promise in a space application.

At the request of the MILSATCOM Program Office, we initiated efforts to evaluate crosslink technologies for EHF payloads and satellite buses. Coordinated all of these efforts with ongoing 6.2 and 6.3 communication system development work at Rome Laboratory.

CHANGES FROM LAST YEAR

We initiated multispectral and hyperspectral projects. We initiated efforts to extend the cutoff of HgCdTe detectors in support of customer needs. We canceled the 60 GHz antenna project. Current funding is not adequate to complete these projects by the technical freeze date. We added a COMUZE (Satellite Communications Commercial Utilization Evaluations) project to evaluate Anti-jam, Low Probability of Intercept, Detection, and Exploitation characteristics of commercial SatComm for military use. The FY96 Active Sensors program emphasizes a renewed focus on an ever-increasing range of signal processing capabilities from space and develops a sensor characterization capability which can better sort these alternatives.

MILESTONES	YEAR	METRICS
Space Sensor Characterization Model	FY97	Provide comprehensive space sensor characterization model
DSB SBR Concept Study	FY97	Define initial parameters of viable SBR
Demonstrate low background LWIR QWIP	FY97	QWIP with 10X improvement in D*
Transition QWIP technology to 6.3 arena	FY97	Initiate development of large QWIP focal plane arrays
Demonstrate two color QWIP	FY97	Simultaneous detection in two bands with high performance
Develop 60 GHz SSPA for integration into Adv. MILSATCOM	FY97	SSPA delivered and integrated
	FY98	Technology available for use in operational systems
Space Sensor Clutter Model Database	FY98	Typify major areas of earth for radar clutter and model results
Demonstrate Large Starring QWIP LWIR Focal Plane Arrays	FY98	Fabricate and characterize 1024x1024 QWIP FPA
Develop large two color FPA	FY99	Demonstrate 1024x1024 two-color QWIP arrays
Develop rapid acquisition modem for integration into Adv.	FY99	Modem delivered and integrated
AF Space Sensor Study	FY00	Define SBR parameters for an EMD decision Technology available

THRUST 7: SPACE VEHICLE ELECTRONICS AND SATELLITE CONTROL

USER NEEDS

Electronics and software are as pervasive in space systems as they are in everyday life. AF SPOs, BMDO, and other space system developers have identified high performance, radiation hardened, space qualifiable, on-board signal and data processing subsystems as critical technologies for the late 1990s and beyond.

To meet these broad, user-defined needs, we must develop and demonstrate technologies that improve microelectronics components. Often technology needs can be directly met by improving the performance, size, reliability, or cost of an electronic component, board, subsystem, or software tools.

Satellite Control programs are firmly rooted in the Operational Requirements Document AFSPC 00-94, Satellite Control, 4 Aug 95 and the Satellite Operations Mission Area Plan, 20 Nov 95. Our focus is on supporting the warfighters and operational users by providing more cost effective satellite command, control, and communications.

Examples of the numerous technology needs identified in specific SMC TPIPT development plans are:

MISSILE WARNING - survivable high speed communications, decision support systems, high fidelity simulators and RF sensor model/simulation tools

RECONNAISSANCE / SURVEILLANCE - radiation - hard 32-bit processors, algorithms, high-speed on-board signal processing and fast target detection

SATELLITE CONTROL -Ground control decision aids, autonomous spacecraft and subsystem operations.

SPACELIFT - autonomous GN&C, advanced power conversion.

MISSILE DEFENSE - Multi-sensor fusion

GOALS

Our overall goal is to permit increased space system reliability, operability, autonomy, and affordability by developing the next-generation of electronics and, software and demonstration of advanced components and methods. Specific Space Electronics goals are:

- Develop and demonstrate essential electronics (including 32-bit processors, memory, etc) for DoD with "spin-off" applications in NASA and commercial satellite programs
- Improve direct information transmission to field commanders by 100% through advanced electronics (e.g., signal processing systems) and algorithms.

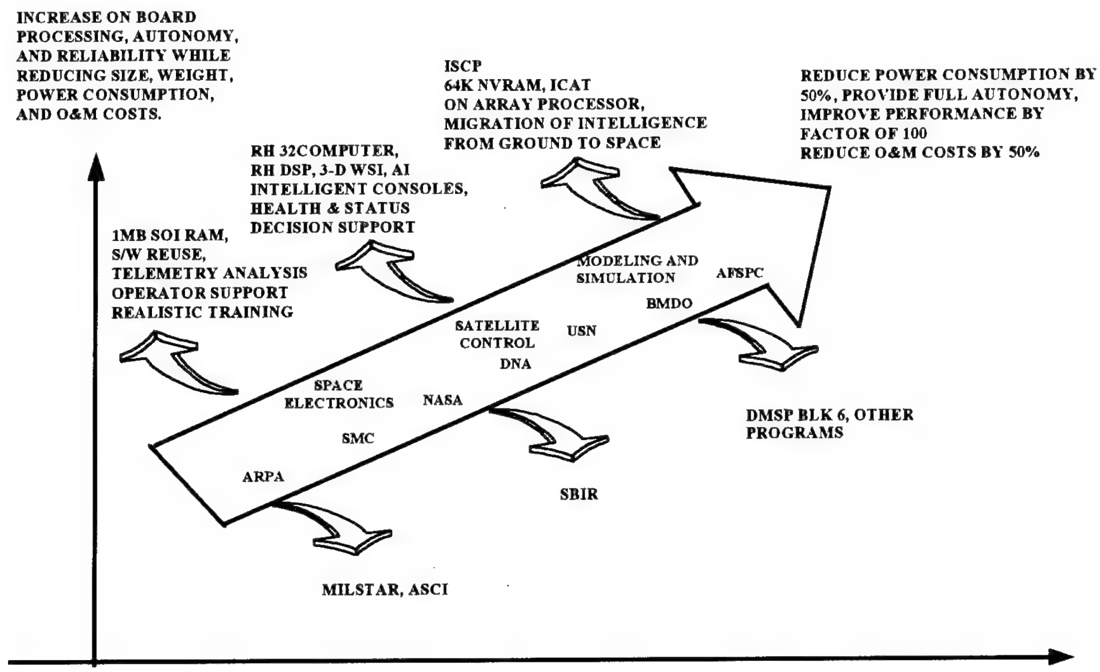
Key developments to meet the above goals are to:

- Provide at least a 10X improvement in AF space electronics systems capability in the next five years by:
  - Leveraging from the rapid progress being made in the commercial electronics industry
  - Transitioning high-demand commercial integrated circuits to space qualifiable versions
  - Leveraging industry's huge commercial investment in design, software, and testability
  - Developing innovative hardening technologies and transferring them to industry
  - Building a standardized space signal processing module focusing on the hardening of a selected commercial processor
  - Demonstrating space qualifiable versions of commercial high speed data busses including the Fiber Distributed Data Interface and the Asynchronous Transfer Mode
- Develop new computer architectures and standards to reduce the customer's cost to develop and test systems by as much as 50%.
- Develop space qualified versions of commercial integrated circuits, MEMS devices, and advanced packages which will:
  - Reduce the weight, volume, and power required by the next generation electronics, reducing battery, solar panel, and overall satellite structure weight thereby allowing use of smaller, less expensive launch vehicles
  - Increase the amount of electronics integration that can occur within a single package by 10X,
  - Improve system reliability by 100% by integrating more functions per electronics package, reducing the number of vulnerable wire interconnects

We address deficiencies in Satellite Control by improving the producibility, affordability, and performance of space systems through space unique software research and development by:

- Developing reusable, affordable software architectures, components, and tools for satellite systems including on-board and ground station processing to reduce acquisition and O&M costs by at least 50% while producing flexible systems that meet current and future needs.
- Developing software concepts to achieve an optimum level of satellite autonomy and develop intelligent consoles for satellite control to improve orbit analysis and control capabilities. Reduce manpower required to control satellites by one third and address improvements in resource scheduling.
- Develop intelligent systems for ground stations to reduce operator workload and assist in anomaly resolution. Develop intelligent systems for satellites to reduce amount and complexity of data transmitted to the ground and improve safety of satellite operations.
- Applying a disciplined engineering approach to the development and acquisition of software to improve the quality of space systems software and meet program

THRUST 7
SPACE VEHICLE ELECTRONICS AND SATELLITE CONTROL



cost and schedule requirements.

- Build the Frontier Arena under AFSPC and SMC sponsorship to be an evolutionary, dynamic, distributed, interactive space M&S environment for technology development, and system development/acquisition.

MAJOR ACCOMPLISHMENTS

We joined with other Government research labs to identify several bipolar integrated circuits now used in space which exhibit lower-than-expected safety margins when subjected to natural space rates of radiation exposure.

We applied radiation hardening design practices to develop a gate array on a commercial fabrication line which has 10 times more hardness than standard circuits.

We completed space hardness of 32-Bit RISC processor by modifying the design to incorporate single-event hardened latches; demonstrated prototype devices.

We developed the first space hardened 800K field programmable gate array by improving and then transferring a widely used commercial design to a space foundry.

We developed a conceptual framework for packaging high-performance, heterogeneous 3-D electronic systems with 100-200X size and weight reduction potential.

Installed the first Multimission Advanced Ground Intelligent Control (MAGIC) system at Falcon AFB Space Operations Complex (SOC) 33. This provides telemetry storage and analysis for the operational life of satellites managed by SOC 33. MAGIC proved the concept of a low cost, flexible satellite control architecture. The 6 stream system was installed for $300K.

CHANGES FROM LAST YEAR

In cooperation with ARPA, we initiated a program to study applications for Microelectromechanical Systems (MEMS) for space. This program will include development of the space-unique technologies to apply this promising technology.

Satellite Control initiated training and automated satellite health status assessment on the MAGIC program. The satellite anomaly resolution phase of Magic is commencing.

Milestones	Year	Metrics
Complete development of space-qualified, commercial heritage digital signal processor single-board computer	FY96	Deliver Ada compatible signal processor running at 28 MFLOPS
Develop and fab space-qualifiable 8K field programmable gate arrays	FY97	Insert FPGA technology in 10 existing or future satellite systems
Develop ultra-thin high density interconnect technology for space	FY98	Demo on space experiment and insert in one future space system
Develop a Training Module of MAGIC	FY97	Customer on-site product acceptance
Develop Methods of Resolving Known Satellite Anomalies	FY98	Customer on-site product acceptance

THRUST 8: SPACE VEHICLE AND MISSILE DYNAMICS TECHNOLOGY

USER NEEDS

The importance of maintaining a reduced nuclear force and emerging conventional ballistic force as a combat and cost effective weapon is recognized by AFSPC mission area plans and SMC development plan technology needs:

NUCLEAR DETERRENCE: Need significant technology infusion as identified by OSD Hard and Deep Buried Target IPT and STRATCOM/JROC approved MNS CAF 317-92. Need to provide technology to sustain Minuteman III as stated in PMD-231304. Guidance Technology needs thrust axis accelerometer, next generation guidance systems and technology, advanced electronics, and hardened electronics. Reentry Vehicle Technology needs munitions technology, RV materials, miniature subsystems packaging, plasma phenomenology and CFD, antenna window, GPS technology, fuze technology adaptive antenna, range instrumentation and flight safety, processing/anti-jam, precision lift and glide control. Relocatable Targets Technology needs high speed processors, ATR algorithms, SAR, E-Optics and cooling systems, RV materials, and antenna window. New Missile Technology needs propellant non destructive test, aging and prediction of Materials Phenomenology, missile propulsion materials applications, large nozzles, fiber optic Built-In Test (BIT) and ordnance initiative, inside-out motor construction, and clean propellants.

CONVENTIONAL DETERRENCE: Significant technology support for the SMC global conventional ACTD and prompt precision weapon delivery is documented in APSPC-CAF 009-3. Rapid Response, Weapon System Lethality, Global Range, and Reliability.

Many of these technologies have additional applications as identified in other Mission Area Plans: SPACELIFT, SPACE SURVEILLANCE, BALLISTIC MISSILES DEFENSE, and NAVIGATION -

The user needs addressed by Astrodynamics are SPACE SURVEILLANCE algorithms for space based sensors in SSN; improved scheduling and tasking algorithms for ground based sensors; improved search, detect and track algorithms for ground based sensors; improved element set initial formation, maintenance and propagation algorithms; and LADAR.

NAVIGATION improved orbit models.

MISSILE DEFENSE tracking/aim point algorithms; and high power laser.

GOALS

Advanced Guidance

- Develop GPS Range Standardization/Safety Tech
- New miniature systems to lower range costs 30% by replacing radar systems and enhance safety with greater accuracy and reliability by FY01.
- Develop GPS accuracy enhancements
- Increase cost effectiveness, missile navigation, testing accuracy with improved GPS/INS coupling by FY98.
- Develop Precision Fiber Optic Gyroscope (PFOG) with low loss integrated optics and fiber couplers and Flexured Mass Accelerometer (FMA) with open loop, two back-to-back microwave resonant cavities by FY99. Decrease reliance on high cost, high precision inertial measurement systems with micromechanical updates on accelerometers and gyros by FY01.
- Fly the Missile Technology Demonstration III (MTD III) during FY01 to gain data on multiple penetrator warheads delivered on an ICBM.
- Develop anti-jam antennas.
- Integrate plasma physics with design.
- Develop and test materials for antenna windows.

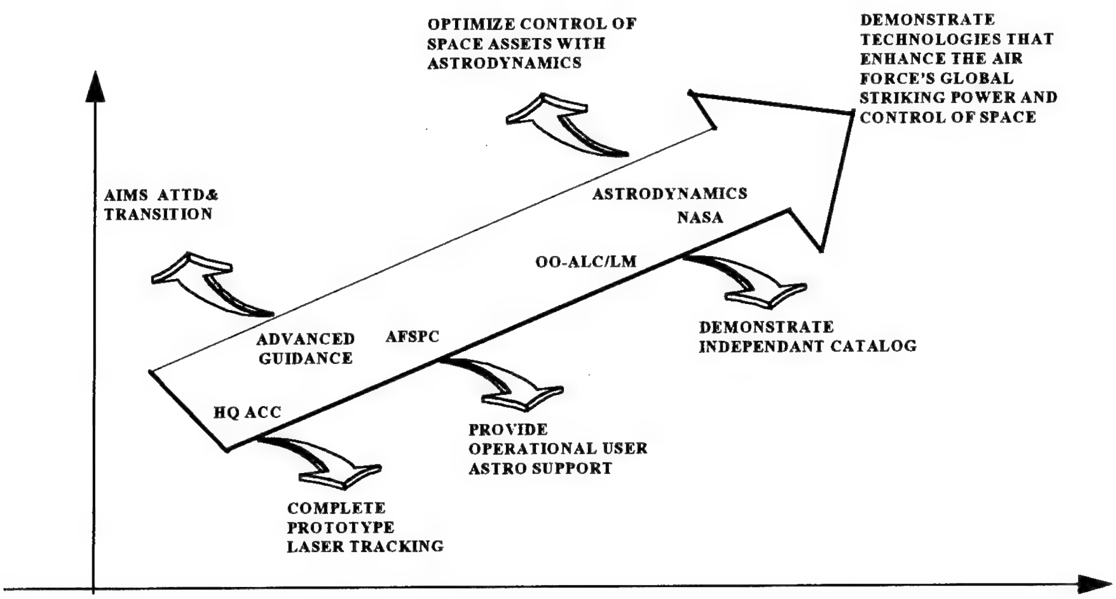
Astrodynamics

- Improve differential correction (DC) accuracy 90%
- Improve propagation accuracy at the end of the prediction period by 90%
- Demo integrated performance of high accuracy lasers and astrodynamics algorithms to precisely locate and illuminate spacecraft
- Demo next generation initial orbit determination, DC and propagation for space surveillance
- Show deficiencies in current operational DC and propagation which could be eliminated
- Demonstrate capability to maintain independent high accuracy catalog of selected satellites (20-30 objects)

MAJOR ACCOMPLISHMENTS

Successful flight of the Missile Technology Demonstration I (MTD I) on 16 August 1995. MTD-1 consisted of a US Army STORM ballistic missile with a modified Pershing II reentry vehicle. The flight provided new empirical data for an 284 lb class penetrator into a geology of interest. A commercial differential GPS/INS package gave extremely accurate range metrics and position information and enabled the impact point to be estimated continuously for an on-board autonomous range safety solution. A Counter Measures Hands-on Program (CHOP) piggy back experiment was also successfully flown. These experiments will result in improvements in range safety and metrics for all space and missile flights. For example, White Sands Missile Range has already incorporated results from MTD-1 into their radar modeling for increased accuracy.

THRUST 8
SPACE VEHICLE AND MISSLILE DYNAMICS TECHNOLOGY



The following accomplishments were completed: 1) SOR laser demonstration, 2) operational support for USSPACECOM , AFSPC and PL, 3) benchmark of operational orbit software for the Space Warning System Center, 4) evaluation of commercially available orbit software.

The final draft of an astrodynamics textbook was field tested in graduate classes at 8 universities. This documents astrodynamic routines and computer code. Use of this new text to train engineers and satellite operators will standardize algorithms and prevent need for stovepiping astrodynamics specialists.

A major research program for astrodynamic parallel processing for propagation and differential correction is continuing.

CHANGES FROM LAST YEAR

Congressional language required Advanced Guidance and Reentry Vehicles be extensively modified. Sufficient funds were added to move Missile Technology Demonstration II (MTD II) forward so that money will be available to finance the flight in FY96. Data from this flight will now directly impact AFSPC's ACTD in 1998.

Responding to Congressional language, the Reentry Vehicle effort was terminated in FY95. Reentry materials are being pursued by the Materials Directorate.

MILESTONES	YEAR	METRICS
Solid State Guidance Instrument Technology	FY98	Guidance instruments one-tenth current size
Adaptive antenna technology	FY98	Demonstrate GPS antijam antenna in ground tests
Precision Fiber Optic Gyroscope	FY99	Increase current bias stability performance specification by order of magnitude
Flexured Mass Accelerometer	FY99	Increase accuracy by factor of 2 while decreasing size and cost by factor of 4 to 5
Missile Technology Demonstration II (MTD II)	FY01	Multiple conventional penetrator warheads delivered by ICBM at 4000fps +- 500 fps and within 5m CEP for each
Implement new propagator in SSC	FY97	Reduce sensor taskings by 25%
Implement independent integrated surveillance system	FY98	Develop algorithms for upgraded SSC which increase performance by 30%
Mission planning support & operations guidance	FY97	Create algorithm for optimal orbit raising and repositioning
Provide model of non-maintainable orbits	FY97	Develop capability to accurately model and track non-maintainable orbits within 20 km

GLOSSARY

A

ACC Air Combat Command
ACTD Advanced Critical Technology Demonstration
ACTEX Active Controls Technology Experiments
AFOSR Air Force Office of Scientific Research
AFSPC Air Force Space Command
ARIES Applied Research In Energy Storage
ARPA Advanced Research Projects Agency
ASIC Application Specific Integrated Circuits

B

BMDO Ballistic Missile Defense Organization

C

CHOP Counter Measures Hands-on Program
CONUS Continental United States

E

ESA European Space Agency

G

GEO Geosynchronous Earth Orbit

H

HEDM High Energy Density Material

M

MANTECH Manufacturing Technology
MTD Missile Technology Demonstration
MAP Mission Area Plan

N

NRL Naval Research Laboratory

O

OTV Orbital Transfer Vehicle

S

SMC Space & Missile Systems Center
SOI Silicon on Insulator
SPO System Program Office
STIG Space Technology Interagency Group
STRV Space Test Research Vehicle

T

TAOS Technology for Autonomous Satellite Operations
TAP Technology Area Plan
TPIPT Technical Planning Integrated Product Teams

U

USSPACECOM United States Space Command

W

WL Wright Laboratory

Technology Master Process Overview

Part of the Air Force Materiel Command's (AFMC) mission deals with maintaining technological superiority for the United States Air Force by:

- Discovering and developing leading edge technologies
- Transitioning mature technologies to system developers and maintainers
- Inserting fully developed technologies into our weapon systems and supporting infrastructure, and
- Transferring dual-use technologies to improve economic competitiveness

To ensure this mission is effectively accomplished in a disciplined, structured manner, AFMC has implemented the **Technology Master Process** (TMP). The TMP is AFMC's vehicle for planning and executing an end-to-end technology program on an annual basis.

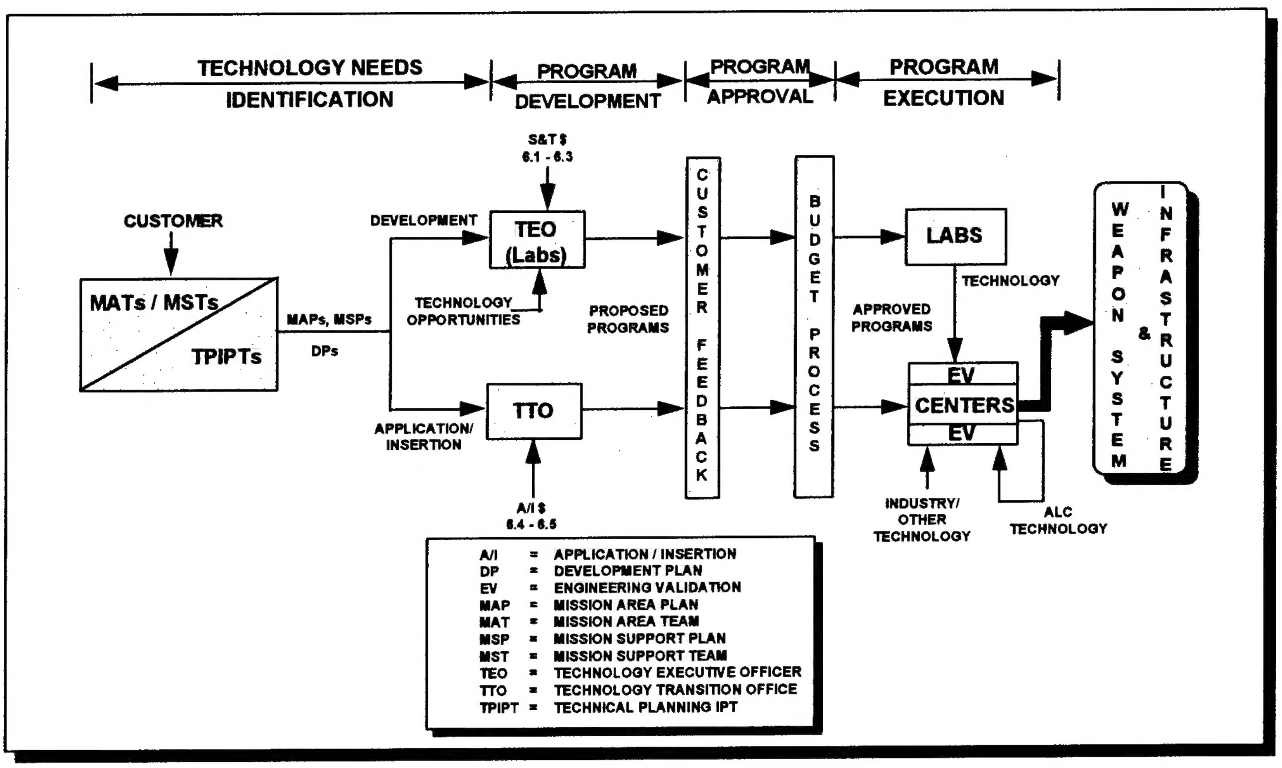


Figure 1 - Technology Master Process

The TMP has four distinct phases, as shown in Figure 1:

- Phase 1, **Technology Needs Identification** -- Collects customer-provided and customer-prioritized technology needs associated with both weapon systems, product groups and supporting infrastructure; then identify them by the need to develop new technology or apply/insert emerging or existing technology. These needs are derived in a strategies-to-task framework via the user-driven Modernization Planning Process.

- Phase 2, **Program Development** -- Formulates a portfolio of dollar constrained projects to meet customer-identified needs from Phase 1. The Technology Executive Officer (TEO), with the laboratories, develops a set of projects for those needs requiring development of new technology, while the Technology Transition Office (TTO) orchestrates the development of a project portfolio for those needs which can be met by the application/insertion of emerging or existing technology.

- Phase 3, **Program Approval** -- Reviews the proposed project portfolio with the customer and obtains approval for the portfolio through the budgeting process. The output of Phase 3 is the authorizations and appropriations required, by the laboratories and application/insertion programs, to execute their technology projects

- Phase 4, **Program Execution** -- Executes the approved S&T program and technology application/insertion program within the constraints of the Congressional budget and budget direction from higher headquarters. The products of Phase 4 are validated technologies that satisfy customer weapon system and infrastructure deficiencies.

Additional Information

Additional information on the Technology Master Process is available from HQ AFMC/STR, DSN 787-6777/8764, (513)257-6777/8764.

INDEX